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Modern Concepts of Cardiovascular Disease

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ELECTROCARDIOGRAPHY IN CHILDREN

Electrocardiography in children and in adults is fundamentally the same, but it is necessary to take into account significant differences in the various intervals and in the amplitudes of the waves.

The P Wave in Lead I averages higher in children than in adults, in Lead II it is about equal, and lower in Lead III. Thus, the upper limit of the height of P in Lead I may be placed at 1.5 mm., and in Lead II, 2.5 mm. The height of the P wave is often above these limits in congenital pulmonary stenosis and in rheumatic mitral stenosis.

Slightly inverted or diphasic P waves of the plus-minus type are sometimes normally seen in Lead III.

The width of the child's P wave should not exceed 0.09 sec. When it is wider, rheumatic mitral disease or a congenital defect should be considered. Uncomplicated patent ductus arteriosus does not affect the P wave.

Notching of P waves whose height is more than about 0.7 mm. is rarely more than minimal in the normal child. Abnormal notching is particularly characteristic of rheumatic heart disease. Notching is rare in congenital defects. A diphasic P of the minus-plus variety, with downward and upward deflections roughly equal, is probably abnormal.

The P-R Interval. From birth through the 5th year the average P-R interval is about 0.11 to 0.12 sec.; from ages 6 to 9, 0.13; from 10 to 12, 0.135; and for ages 13 and 14, about 0.14 sec. The P-R should not exceed the average figure for the age by more than 0.02 sec. when the heart is very rapid, or by more than 0.04 sec. when the heart rate is low. The range of the uper limit of the normal in children will thus extend from 0.14 to 0.18 sec., depending on age and heart rate. Prolonged P-R intervals are discussed below under disturbances of the heart mechanism.

The QRS Complex. At birth the QRS complex reveals a right axis deviation, the angle often being as high as +130°. During the next several months the axis rotates to the left, reaching an average of about +52° at 3 years. Then, as the length of the thorax increases with age, there is a rightward rotation until, just before puberty, the axis is about +67°. From puberty to middle age there is probably again a slight leftward rotation.

Excluding infants, the normal limits of the average electrical axis of the QRS ranges from about +20° to +105°, although occasionally the axis will lie outside these limits in the absence of heart disease or congenital defect.

The most extreme right axis deviations are seen in congenital pulmonary stenosis, associated or unassociated with other defects. Abnormal right axis deviation is rarely found in uncomplicated cases of interventricular septal defect or patent ductus arteriosus, nor is it seen in coarctation of the aorta. It often occurs in rheumatic mitral stenosis, but slight to moderate degrees are often seen in normal, slender children. *Ceteris paribus*, the purer and more extreme the stenosis, probably the greater the axis deviation. An associated aortic insufficiency or stenosis may offset the rightward deviation, or even over-balance it so that left axis deviation appears.

The incidence of factors causing left axis deviation in children is lower than of those causing right. They include aortic stenosis and insufficiency, hypertension, coarctation of the aorta and, probably, mitral insufficiency without a functionally significant stenosis. Abnormal left axis deviations are often absent in all these conditions.

Because of the smaller heart size in children, the width of the QRS complex is less than in adults. The upper limits of the normal can safely be placed at 0.08 sec. for younger, and at 0.09 sec. for older children. This interval is sometimes slightly lengthened by rheumatic heart disease and less often in congenital defects.

Low voltage of the QRS is rare in children, both in the presence and absence of heart disease. High, bizarre complexes suggest a congenital condition.

The Q Wave. When right axis deviation is present, a Q wave of 4 or 5 mm. in depth is not abnormal in Lead III in younger children. The Q wave should never be so wide as to appear distinctly slurred.

The R Wave in children differs little if at all in height from the R of the adult. R waves exceeding 22 mm. are most commonly seen in congenital defects. The R in Lead II is normally nearly always higher than, or as high as, R-1.

A slur of the R upstroke, aside from a slight, smooth hesitation near the base, or a slur at or near the apex, is much more significant than a slur on the lower half of the downstroke. The duration of the R upstroke should not exceed 0.035 sec. A slur which might be regarded as border-line in the adult will usually mean heart damage in the child. The higher the R the more significant the slur; slurring and notching of low QRS complexes in Lead III are without significance. Rarely, a relatively low R-1 will be notched in the absence of disease. If a moderate left axis deviation is present, slight upward slurring of R-2 is normal. Slurring and notching are encountered in a considerable percentage of rheumatic, and in a larger proportion of congenital pulmonary stenosis cases. Children with

diphtheria sometimes have slurred QRS complexes.

The S Wave may be abnormally slurred or notched when the heart is abnormal. The depth of the S wave is not important apart from the average electrical axis of the QRS complex.

Right Bundle-Branch Block has been seen in apparently healthy children. *Left Bundle-Branch Block* is a rarity in the child. *Pseudo Bundle-Branch Block*, with wide QRS complexes, R-1 (or/and R-2) being slurred upward, and the P-R interval being short (0.09 or 0.10 sec.), is sometimes seen. These children may experience attacks of paroxysmal tachycardia. Exercise or atropine may abolish the QRS deformity and lengthen the P-R. These pictures are not evidence of disease, and have been attributed to an accessory A-V bundle (of Kent).

The RS-T Segment is rarely long in the normal child's picture. It is frequently absent, the T rising directly from the R or S.

High or low take-offs of the RS-T segment from the R or S wave are sometimes seen in the normal, but the shift should be less than 1 mm. In heart disease, particularly rheumatic, and pneumonia, greater deviations may occur. An acute pericarditis often causes an upward shift in all three, or in two, leads.

The T Wave. The average height of T-1 in children is slightly greater than in adults; in Lead II they are about equal; and those of children average less in Lead III. The average height of the T waves in boys is slightly greater than in girls, at least after age 5. Neither rheumatic heart disease nor congenital defects affect this sex difference. After early infancy, at which time the T waves are often low, age probably has little or no effect on the manifest potential of T. The average heights in rheumatic heart disease do not differ significantly from the normal, though low T waves in all leads are sometimes encountered. On the average, the T-wave amplitude is increased in congenital malformations.

In contrast with the normal adult, in children T-1 is rarely lower than T-3. In rheumatic carditis there is a tendency in some cases for the electrical axis of T to rotate to the right, the result being a low T-1 and a higher T-3. In a smaller proportion of cases the rotation of the T axis will be to the left, and this may even result in inversion of T-2.

In the normal child inversion of T-3 is somewhat more common than in the adult. Among children convalescent from diphtheria, the incidence of inverted, diphasic or isoelectric T-3 waves is still greater (nearly 70 per cent).

As in the adult, inversion of T-1 is distinctly abnormal, as is inversion of T-2 in practically all cases. Such inversions are occasionally seen in rheumatic carditis and may come on with the drying-up of a pericardial effusion. They may appear in acute infections such as typhoid fever, scarlet fever, upper respiratory infections. In diphtheria abnormal T-wave inversions are usually associated with marked QRS-complex changes, the latter being of ominous significance. In diphtheria also, and not infrequently in rheumatic carditis, the T waves, though of normal height, are often rounded and their downstrokes may be of diminished steepness.

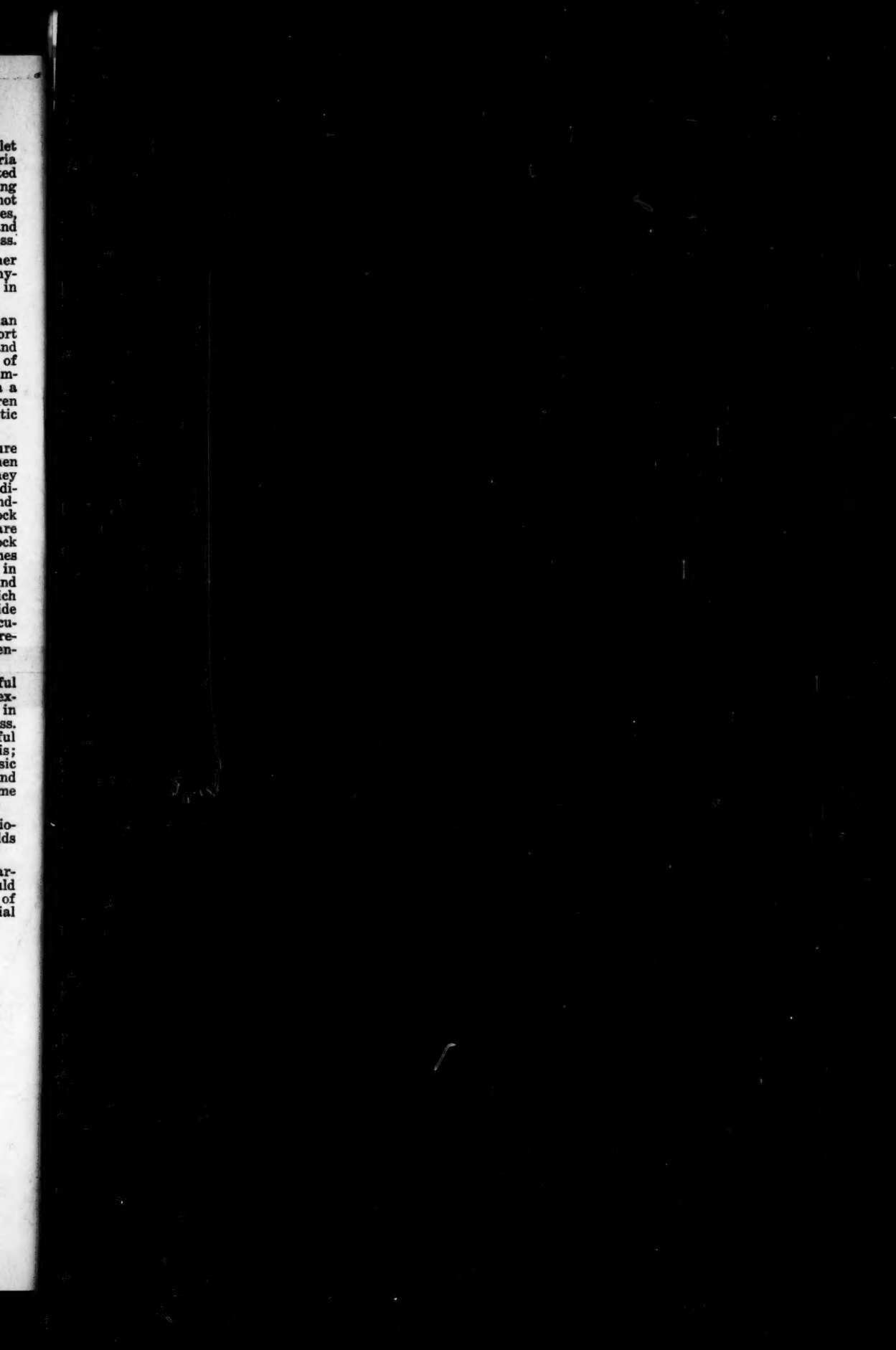
Notching of the T wave in children is rather rare and is usually due to rheumatic carditis, hyperthyroidism being the more common factor in the adult.

The Q-T Interval depends far less on age than on heart rate, though it tends to be relatively short in young children. In older children, both male and female, the Q-T is practically the same as that of adult males. Hypocalcemia appears to be an important factor in lengthening and hypercalcemia a factor in shortening, the interval. In many children recovering from diphtheria, or who have rheumatic carditis, the Q-T is prolonged.

Disturbances of the Heart Mechanism. Premature beats of any origin are occasionally found when clinical evidence of heart disease is lacking. They are commoner, yet rather rare, in rheumatic disease. Prolonged P-R intervals are a common finding in rheumatic carditis, and partial A-V block may develop under digitalis medication. They are likely to be evanescent. Rarely, complete A-V block may occur in rheumatic carditis. It is sometimes congenital. When the heart is seriously involved in diphtheria, heart block is a usual finding; and sometimes an idioventricular rhythm develops which is faster than the auricular rate. In these cases wide and bizarre QRS complexes are the rule. Auricular fibrillation and flutter in children are very preponderantly associated with rheumatic mitral stenosis.

Lead IV. This derivation is not today so useful in children as in adults. It may sometimes be expected to pick up an RS-T segment shift, e.g., in pericarditis, which the standard leads may miss. Serial Lead IV records have been reported as useful in following the progress of a rheumatic carditis; but it must be remembered that upright or diphasic T-IV waves are common in normal children, and there may be spontaneous variations from time to time.

Prognosis. Just as in adults, the electrocardiogram is useful in prognosis only insofar as it adds to the completeness of the clinical picture.

In conclusion it should be stressed that departures from the normal, of a degree which would be merely suggestive in the electrocardiogram of an adult, are generally significant of myocardial disease in the child.

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